Appendix G
Biological Considerations

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Ultimately, the Aquatic Habitat Guidelines program intends to offer one complete set of appendices that apply to all guidelines in the series. Until then, readers should be aware that the appendices in this guideline may be revised and expanded over time.

It is necessary to know as much as possible about the life-cycle needs of fish and wildlife in order to predict the impacts of a streambank-protection project, to design for the minimum impact and to plan for the mitigation of unavoidable negative impacts. What happens in the water directly affects fish, of course, but what happens in the area along the bank (riparian area) also directly affects them. The riparian area is also where other wildlife live; numerous bird species, mammals (large and small), insects and amphibians all spend part or most of their lives in areas adjacent to water.

Salmonid fish species are emphasized in this appendix. Salmonids discussed here are all species of Pacific salmon, char (known as Dolly Varden and bull trout), steelhead, rainbow trout and cutthroat trout. It is reasonable to believe that, if we take care of the habitat needs of salmonids, we will satisfy the needs of many wildlife species as well. This is assuming that such care involves restoring and protecting natural stream conditions and processes such as velocity, diversity, ample hiding cover, shade, overhanging vegetation, access to sloughs and the presence of backwater habitat adjacent to faster flow.

While much has been written about the life cycles of salmonids, less has been written about their specific habitat needs, and even less has been written about the impact of streambank disturbance on the species' habitats. While the amount of data regarding the habitat effects of bank-protection activities is lacking, we can make logical and defensible assumptions about their effects based on the specific habitat needs of various fish species. There are certain habitat needs that are common to all species of salmonids. This information is presented first by general habitat needs at each life stage: egg/alevin, fry, smolt and adult. A description of specific needs for each species follows the general description.

GENERAL HABITAT NEEDS OF SALMONIDS

The Salmonid family includes a number of fish species that have similar body structure and life cycles. Salmonid species include salmon, char (known as Dolly Varden and bull trout) and trout. Salmonids hatch in freshwater streams, but most migrate from those streams as they mature. Some species spend their entire lives in freshwater (nonanadromous), while other species migrate to saltwater (anadromous) where they spend the majority of their adult lives (see *Figure G-1*).

Most salmonids return to the freshwater stream where they began their own lives to lay their eggs in a nest (redd), which they dig with their tails in the gravel of a streambed. (There are some exceptions, such as steelhead trout, which may spawn in a stream that is not their stream of origin.) The eggs incubate in the gravel for weeks or months, then hatch into a form called "alevins" (hatchlings whose yolk sacs are still attached). They may live for some time in the gravel streambed, but they eventually emerge as very small fish called "fry." They stay in freshwater for a certain length of time, depending upon the species. At some point, the anadromous species begin their migration downstream to the ocean, all the while undergoing a physiological change to adapt to saltwater. Fish that are undergoing this change are called "smolts." After a number of years in the ocean, the anadromous fish mature and return to their river of origin as adults to lay and fertilize their eggs, thus completing the cycle. Some salmonid species die after spawning, while others survive to spawn again.

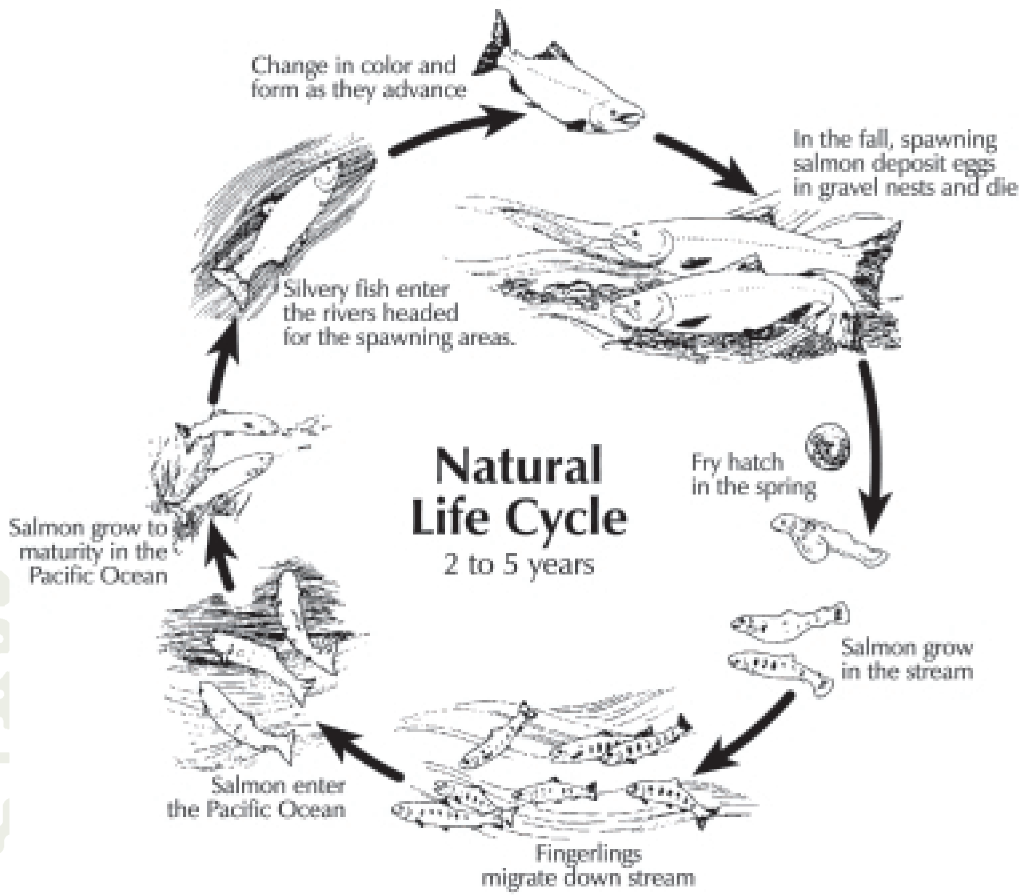

Figure G-1. The life cycle of anadromous salmon.

Salmon, char and trout use different freshwater habitats for different stages of their lives. These life stages are described in general terms as follows:

Adults

Adult salmonids need access to upstream spawning areas with minimal obstacles that could cause delay. If they are returning from saltwater, they need frequently spaced holding habitats from the river mouth upstream to the spawning areas. Holding habitats include deep-water pools and near-shore scour pools with dense cover in the water and above the water. They also need deep, midchannel pools adjacent to spawning areas, large woody debris and bank vegetation, all of which serve as refuge during spawning. The velocity breaks provided by scour pools create much-needed resting sites as well. Because some species enter freshwater in the spring and summer and hold for several months before spawning, they need well-oxygenated, cool, deep holding pools where harassment by predators and other forms of stress are minimized. Access to river braids, side channels and upwelling sloughs is needed during spawning season for species that use such areas.

As mentioned earlier, most salmonid species die after they spawn, and there is increasing evidence that their carcasses add significant amounts of nutrients to streams where they spawn and to the surrounding uplands (where eagles, bears and other predators carry them for feeding). Entire riparian ecosystems depend to varying degrees on the nutrients provided by salmon carcasses. Sufficient debris and backwater areas are needed to capture these carcasses.

Eggs/Alevins

Eggs and alevins need stable gravel and cobble substrate at just the right size for their particular species. They need substrate that is not compacted and is low in fines (small particles of clay, silt and sand less than 0.85 mm in diameter) to allow adequate flow of well-oxygenated water within the gravel spaces. Complex habitat is needed in the form of boulders, logs, log jams, sticks, rock ledges, etc., to sort gravels and dissipate energy while keeping the channel form relatively stable. Even minor increases in the depth of scour may significantly reduce embryo survival. Eggs and alevins prematurely scoured out of the substrate are unlikely to survive. Eggs and alevins deeply buried by shifting substrate may suffocate or may not be able to emerge from the gravel. The natural function of floodplains should be preserved so that high water can flood, thereby minimizing bed scour in spawning areas. High flows are needed periodically through side channels to clean up the gravel, move debris along and generally refresh the spawning area.

Stream or habitat alterations that concentrate flow in the main channel or in a portion of the channel cross section can cause the loss of spawning habitats or affect the stability of the bed and, therefore, survival of eggs and alevins. For example, projects that make a streambank smooth tend to cause a concentration of flow along the bank. This can cause a change in cross-sectional shape that eliminates an on-site spawning riffle. The resulting high-velocity thread may periodically scour a downstream spawning riffle.

Juveniles/Presmolts

The juvenile life stage is especially affected by bank-protection and flood-control activities. Juveniles depend on cover for protection from predation. They also depend on rearing habitats, including resting and feeding stations. Juveniles that are larger in size by the fall will survive the winter and ocean life stages in greater numbers than smaller juveniles. Instream cover may be useful to segregate species and visually reduce aggressive interactions, thereby promoting fish growth and survival. All salmonid juveniles require high-quality rearing habitats with enough food and vegetation resources to support prey. Water velocity and cover are the primary variables governing microhabitat selection by juvenile salmonids in summer.

Movement during the winter into low-velocity microhabitats with good cover is common among many stream-dwelling, juvenile salmonids. Winter cover can consist of large rock rubble with large interstitial spaces; large and small, complex woody debris; undercut banks with submerged vegetation; and deep pools and off-channel areas. Off-channel rearing habitat in floodplain channels is also important winter habitat. Bank-protection activities may preclude the future development of new off-channel rearing habitats by fixing the channel in its current location. Channel degrading or flood-control activities may severely limit access to off-channel winter habitat.

Smolts

The specific habitat needs of smolts are not well known. There is reason to believe that cover plays a critical role in smolt survival. In most Pacific Northwest rivers, smolt out-migration occurs primarily in spring, often during freshet conditions (i.e., during higher river flows caused by rain or melting snow). Smolts migrate downstream primarily at night. During the time when these fish are not moving, they need a safe place to hold and feed, presumably in low-velocity water with good cover. Vegetative cover and velocity breaks high on the bank, even if used only during freshets or floods, may be very important habitat for migrating smolts. It is assumed that approximating a natural, well-vegetated bank at out-migration water levels will produce smolts in better physical condition (well fed and physiologically ready for the sea) than a smolt migrating through a channelized (hard-sided) river. As anadromous smolts travel downstream and enter saltwater, they go through complex physiological changes that enable them to live in saltwater. This transition requires exacting water-quality conditions and habitat features, details of which are beyond the scope of this document.

FISH HABITAT USE DURING FLOODS - FLOOD REFUGE

All adult and juvenile fish need a way to hold in the stream or on the floodplain during flood events. Refuge materials may be provided by relict river channels and sloughs, lakes and ponds, log jams and other large and small pieces of wood, large rock rubble, and riparian vegetation. There may be little in the way of flood-refuge materials left in diked and riprapped river sections. For juveniles dislodged from their winter locations by flood flows, it may not be possible to get back upstream to suitable wintering habitat. Each successive, high-water event increases the chances that these fish will be swept out of the river. Eggs, alevins and presmolts that are prematurely washed to sea during high flows do not survive in significant numbers.

During floods, fish may move to areas with more cover or areas with slower stream flow within a river to minimize the flood's impact on them. Water velocity and depth are important factors in determining refuge suitability. Chinook and steelhead tend to use large-boulder and cobble habitat, whereas undercut banks and instream debris are preferred by coho and cutthroat trout. Fish that live near the edge of the river may respond to floods by moving laterally within the river to stay close to the shoreline regardless of the flow. Log jams that may otherwise be high and dry on gravel bars and banks may become very important refuge during floods. Research has shown that, during floods, brown trout and nonsalmonid species seek areas outside the low-flow channel with depths and velocities similar to what they are accustomed to at lesser flows.

Fish may move laterally for a number of reasons. Fish may move into temporarily flooded areas of the stream margins to feed. They may feed on terrestrial animals such as small insects, amphibians, birds and even small mammals. Juvenile brown trout have been found feeding at higher than normal rates during floods. Fish may move to slower-flowing water to avoid being swept away. By moving to shallower areas, fish are less susceptible to predation by larger fish. However, in these shallower areas they become more susceptible to predation by birds and mammals, so cover is essential.

HABITAT NEEDS OF PACIFIC NORTHWEST SALMONIDS BY SPECIES

Chinook Salmon

Chinook salmon behavior and habitat needs in freshwater are complex and may differ from one stream to the next. Habitat requirements may vary among sizes of streams and seasons. In any given river, there may be races of fish that return as adults in the fall, some in the spring and others in the summer. The juveniles of these various races also differ in their behavior and habitats.

In large rivers, young chinook are frequently seen near the water's margins. They move to deeper water as they grow. In the Skagit River in western Washington, chinook are found most frequently in backwater areas and along natural bank lines, less frequently next to armored banks, and even less frequently near sand bars. According to U.S. Army Corps of Engineers studies on the Sacramento River in California, the least-preferred habitat for chinook is riprap revetments.

Chinook generally spawn in the fall and winter, and the fry emerge in mid- to late spring. Habitat needs of chinook during the summer change as fish grow and as water flows change. In small mountain streams, summer habitat is most often provided by undercut banks where water velocities are less than 20 cm/s and depths are 20 to 80 cm. In large rivers, chinook use quiet-water scour pools associated with logs and roots at the edge of the channel. As fish become larger, they select faster and deeper habitat farther from the banks. Age-zero chinook (fry less than a year old) can tolerate faster and deeper water than can steelhead of the same age. Juvenile chinook occupy feeding stations that allow them to hold position in water with a low-velocity, usually near the stream bottom, but near high-velocity flow. This allows fish to dart into faster current to prey on drift insects and then return to the slower water to rest. In turbid, glacial rivers, they frequently hold behind boulders. In larger rivers, chinook most often can be found at depths of 30 to 100 cm where velocities are less than 50 cm/s. They are found on the margins of sand bars, closely associated with woody debris, even debris as small as a pencil.

In British Columbia, researchers reported the numbers of yearling chinook were positively correlated with rock size, water depth and velocity during freshet flows in June, but were found in lower-velocity zones in September. In late summer on riprap banks, chinook were found more often around larger rock than smaller rock. In late winter, they may be found more around large riprap than small riprap. Near riprap, the near-bank velocity has a large effect on yearling chinook distribution; they hold in low-velocity zones associated with large rocks, but the low-velocity zone needs to be near a high-velocity zone.

In winter, chinook are consistently very near the surface, away from the large steelhead located near the bottom of deep pools. Chinook generally are not found in riffles in the winter. In rivers, chinook can make extensive use of off-channel areas with slow-moving water. Age-zero chinook move into winter cover when water temperatures fall and stream flows rise. Winter cover for fish of this size usually consists of large rubble and cobble with large, interstitial spaces. During very cold weather, nearly all chinook live among rock piles in the stream or river. When cobble is added to undercut bank areas, chinook use these undercut areas much more than before. Juveniles can survive damage from harsh, ice-scouring conditions if they can enter substrate crevices. Fine-sediment filling of these crevices makes them unusable by chinook. In large rivers, juveniles often use sloughs and backwaters for winter habitat, especially areas fed by warmer spring water.

Steelhead and Rainbow Trout

Steelhead spawn in the spring, and the fry emerge in late spring to early summer. Steelhead may stay in freshwater two or three years before becoming smolts and migrating to the ocean. Steelhead are mostly found in faster water and riffles. They are often concentrated in riffles and glides around wood. In cobble and boulder beds with no wood, cobbles will be used by all sizes of trout more often than large boulders. Steelhead are also found in deeper pools near obstructions. In larger rivers, steelhead may be found near the bottom in 15 to 20 feet of depth in the lee of obstructions that serve as holding and feeding stations.

When threatened by a predatory fish, recently emerged fry hide in the gravel, while older individuals take refuge in cover, such as woody debris. When in the presence of coho, steelhead segregate themselves and occupy the lower third of the water column and riffles. Age-zero steelhead use the shallowest and slowest water. Larger steelhead use the deeper and faster water.

Microhabitat selection by steelhead and rainbow trout varies among fish sizes and seasons. Fish of the same size use very different habitats in the summer and winter. In summer, rainbow trout prefer the same dense, vegetative shade that cutthroat trout do. For steelhead, overhead cover may not be as important; instead, they may need fast, shallow-water habitat with large-particle substrate, such as cobbles and boulders. All size classes prefer to hold close to the bottom.

Steelhead begin to change their preference for habitat in the fall as conditions change from summer to winter. Winter cover may be far more important than summer cover. In fall and winter, steelhead relocate as water temperatures drop if suitable habitat is not available. Both juveniles and adults prefer slower and deeper water than they do in summer. This movement to slower, deeper water in the winter may culminate in juvenile fish taking refuge in the substrate during very low temperatures. Steelhead in winter tend to seek out cover around boulders, rubble and log jams; at low temperatures, age-zero steelhead are most often found amongst and under rubble and cobble having substantial interstitial spaces.

Numbers of age-zero steelhead in small streams are lower at riprap sites than at other types of habitat. In a British Columbia study, numbers of steelhead yearlings and older fish increased with larger rock size and increased water depth and flow during June high-flow conditions and September lower flows. They appear to prefer higher-velocity water (or at least access to it), near big rocks in deeper water. They establish feeding stations near large riprap at the toe of the bank. Age-zero steelhead were found in greater numbers at sites with larger riprap than with smaller riprap. When boulders were added to riprap banks, the number of age-zero steelhead in summer decreased, while yearlings and older fish increased.

Cutthroat Trout

Cutthroat trout make extensive use of small streams. Cutthroat are present in most small streams, together with coho salmon and steelhead. Cutthroat can exist as resident fish, spending their entire lives in freshwater, or they can follow the anadromous life cycle. Both forms of cutthroat can exist in the same watershed. Anadromous cutthroat tend to spawn in the small headwater tributaries of larger streams and live in freshwater from one to six years before they become smolts. Cutthroats tend to spawn higher in a watershed than coho, and they rear near their spawning areas.

After emergence, fry quickly drift downstream into low-velocity margins, backwaters and side channels adjacent to the main channel. In the absence of competition by other species, such as coho, they may remain in these margins throughout summer. Because of their larger size and predatory nature, coho drive age-zero cutthroat from pools and margins into riffles. The cutthroat stay there until decreasing water temperatures and increasing flows in the fall drive them into winter habitats. In the spring, migratory age-one cutthroat begin their downstream movement to the main stem of the stream. In the fall, at the onset of freshets, there is often an upstream movement back into the tributaries.

In small streams, cutthroat prefer dense, vegetative shade in summer. Pool habitat is very important. They are often found in deep pools, with larger fish in deeper pools, in lateral scour pools along deeply undercut banks and around submerged objects. They can be found in large numbers in pools with and without wood and in riffles and glides with wood. Cutthroat like backwater-slough habitat with slow water and plenty of good cover, such as log jams and overhanging vegetation.

Winter habitat for adults and subadult prespawners are deep holes, undercut banks and debris piles. Off-channel pools and side channels are also important winter habitat.

For those smolts that are anadromous, their migration occurs in spring, primarily at night. Smolts may spend considerable time in estuaries during their first summer. Most move back into the freshwater in the fall to winter over, and cutthroat subadults may return from saltwater in the fall to estuaries and freshwater in order to feed. Anglers often fish for them from the shore, around log jams and other woody debris. In streams, these fish may be found in deeper pools around cover such as wood. They may occupy the same winter habitat as larger presmolts.

In a study of small streams, the total weight of all cutthroat living along shorelines with riprap was less then along similar shorelines with no riprap. In large streams, the number of large cutthroat increased at riprap sites, as opposed to along shorelines without riprap.

The Chars known as Dolly Varden and Bull Trout

Fish belonging to the classification known as "char" are differentiated from other salmonids by their small scales and light-colored spots on their skin. Dolly Varden and bull trout are the only native char in Washington. Both Dolly Varden and bull trout occur in coastal and Puget Sound streams; however, only bull trout are known to occur east of the Cascades. Both can be present in the same watershed in western Washington. Char have a number of different, complex life cycles. Some are life-long residents of headwater streams, while others spend their adulthood in the main river or in lakes but ascend into small, headwater streams for spawning and juvenile rearing. Some are anadromous, some are not.

As adults, char feed primarily on other fish. It may be that a vigorous population of char requires an abundant forage fish such as mountain whitefish, various salmonid species and sculpins. Adult growth can be very rapid in saltwater and reservoirs. In saltwater, they feed on surf smelt, herring, sandlance, and pink and chum salmon smolts.

Char can live 10 to 15 years. Those adults that remain in freshwater live in pools in winter, spring and early summer. They hold in deep pools, long runs with cover, undercut banks and log jams. If a pool gets too shallow, they may move into whitewater around large boulders and surface turbulence.

Spawning is initiated at stream temperatures that are colder (usually below 9 degrees Centigrade) for char than for other salmonids. Spawning habitat for char is farther upstream than for any other anadromous fish. In western Washington, 95 percent of Dolly Varden and bull trout spawn above an elevation of 300 meters (984 feet) or in streams with very cold temperatures similar to high-elevation streams. Many stretches of streams at higher elevations flow down steeper gradients, and this washes away gravel and cobble of suitable size for use by spawning char. However, suitable gravel and cobble may persist in stream stretches at higher elevations where the gradients are less steep or where large logs and log jams form and maintain deep pools. It's in these places that char generally find patches of suitable gravel and cobble in which to spawn, as long as the stream temperature remains within an optimal range for char. Where side channels and wall-based channels exist, logs and log jams can be very important to char.

Shortly after spawning, adults often move back down the river and can be found in the quiet water of deep pools and long, slow runs. During winter, fish that have spawned may feed very little and show little growth. However, those that associate with spawning salmon feed on drift eggs and retain their body condition. After spawning, anadromous adults migrate downstream throughout fall and winter to enter the estuary in the spring. They remain in the estuary until early to midsummer, when they go back upstream to spawn again. Upstream movement can be very fast, often during low-light conditions at dawn and dusk. Once at the spawning ground, they may remain in the same pool or area for several months. All char spawn in the fall.

Eggs and juvenile char require very cold water. Optimal water temperature for incubation is 4 degrees Celsius. Juveniles optimally rear in water 4 to 10 degrees Celsius. Nursery areas for char are near the spawning areas. Rearing habitat can be highly variable. Newly emerged fry are very secretive and are closely associated with large substrate such as large cobbles, boulders and large woody debris. In Oregon, bull trout were most often observed over sand and gravel-sized substrate, independent of stream size and season. They are usually associated with the deepest and largest pools. Juveniles can use stream margins and side channels for rearing. When char are around large rocks, they often seek cover in crevasses between the rocks during daytime, emerging after dark. When juveniles are with other species, they hide in heavy cobble and debris jams. Char can sometimes be found in large numbers in side channel habitats near heavy cover, much like coho off-channel habitat. Boulders and cobbles provide cover in high-gradient sections, and large wood does the same in lower-gradient sections.

Juveniles remain in their natal streams until age two. Those with a resident life history strategy will remain in their natal stream for their full life cycle. Some (adfluvial) will move to large reservoirs, while others (fluvial) will migrate to larger mainstem reaches to rear. Other sub-adults may move out of headwater streams and become anadromous. These anadromous smolts migrate in the spring to live at river mouths and nearby beaches.

Char are very susceptible to changes in land use. Char populations can be limited by increased water temperature, scouring from increased stream flows and insufficient large woody debris. Bank-protection projects that remove trees and overhanging cover in the upper-watershed nursery areas can be particularly damaging to char. Projects that remove log jams and other debris will change or eliminate pools, greatly affecting adult holding sites and juvenile rearing.

Coho Salmon

Coho salmon juveniles are consistently associated with cover. In small streams, they are most often found with cutthroat in deep-shaded pools with wood debris. They are found at undercut banks with overhanging vegetation and around and under logs, stumps and sticks. Coho densities increase with increasing amounts of wood in riffles, glides, pools and side channels. Increasing roughness can create pools and velocity diversity, both of which attract coho. Coho use cover when it is present in pools, but they'll still use the pool even if cover is absent; they simply go deeper for protection. When there is overhanging cover, coho move around more than when the only shade is formed by higher vegetation such as trees. If woody debris is removed from streams, there is a reduction in the density and total production of coho.

Coho prefer a variety of habitats throughout the year. Fry in the spring are found in all habitats, but are primarily at the channel margins. Their densities are greatest in backwater pools and off-channel areas. As they grow, they shift into deeper habitats. In winter, they again shift into areas such as beaver ponds and off-channel habitats with the lowest velocities and turbulence during freshets. Coho populations are limited by total pool volume in the summer. Low stream flows can greatly decrease coho survival. Coho occupy a wide range of habitats in summer, including pools, side channels, beaver ponds, glides and the edges of riffles. When threatened by a predatory bird, coho seek cover. Recently emerged fry hide in the gravel substrate to escape a predatory fish, while larger fry seek woody-debris cover. At lower flows, overhead shade is very important as hiding cover.

Coho tend to be found at middle depths in the main body of pools. Coho select a lower position in the water column when the only cover is water depth. When in streams with yearling steelhead, coho are found higher in the water column, with steelhead deeper or in riffles. Conversely, when sharing waters with younger steelhead and Dolly Varden, age-zero coho are usually in deeper water than these fish. Coho select feeding stations based on water velocity and food supply; the greatest amount of insect drift is in higher-velocity water. They feed primarily on terrestrial insects.

During fall freshets, coho juveniles seek the quiet water of off-channel habitats. Cover may be much more critical for coho in winter than in summer. The most suitable winter habitat for coho combines low flow velocity, shade and three-dimensional complexity. Colder water and increased stream flow may trigger this shift into winter habitat. Many coho must winter over in streams and in main-stem habitats rather than their preferred off-channel areas. In streams, they prefer areas of deep pools and undercut banks with lots of wood, perhaps because of the low flow velocities in pools and in the lee of obstructions. Juvenile coho are generally absent in main channels lacking cover. Where sloughs are limited, coho are very dependent on structural complexity and cover to survive. Survival in winter is strongly correlated with habitat complexity and the amount of woody debris. In winter, at lower temperatures, coho feed less and move closer to low-velocity areas and cover such as logs and upturned rootwads. In very cold weather, they appear to bury themselves in the cover structure, being almost comatose.

Wood provides protection from predators and provides lower flow velocities that help to keep fish from being displaced downstream during freshets. As the water flow increases, fish accumulate in the back eddies behind cover structures and swim against the eddy. At maximum flows, they are found close to cover structures; otherwise, they are either flushed out or they swim away. During daylight, at high flows, fish hold position in the lee of an obstruction. The smallest fish may be the most susceptible to being swept away. There may be a decline in the juvenile coho population in streams after freshets. After freshets, higher numbers of coho remain in stream sections with accumulations of wood than in other habitat types.

Riprap provides very poor habitat for coho. In both small and large streams, coho numbers decrease at riprap sites. Riprap does not provide winter habitat for coho. Bank- and pool-alteration activity can have severe impacts on coho populations. Removing overhead shade also has negative effects.

Chum Salmon

Chum typically emerge from the gravel at night and immediately migrate downstream to the estuary. Most migration occurs at night, although increased turbidity can lead to daytime migration. Chum show a greater tendency to migrate during the daylight in years when pink salmon are present. They also change their vertical distribution when pinks are present.

Chum may actively feed while migrating downstream, especially at night. Some delay migration to feed and have extended freshwater rearing (two to four months). Rearing can occur in backwater sloughs, off-channel habitat, and in quiet backwaters and eddies typically used by coho. Chum may be seen in the shallow margins of sand bars closely associated with both large and small (pencil-thin) wood debris. They may be seen immediately adjacent to the river bank during daytime. In British Columbia's Fraser River, chum are distributed randomly across the river. In smaller streams, chum migrate in the stronger currents in the middle of the stream.

Due to their limited freshwater residence, there may be very little impact of bank protection on chum salmon fry. Bank protection may limit their ability to find cover during their daytime layovers. Secondary impacts of bank-stabilization activities, such as a change in species composition, may have a significant impact on juvenile chums.

Pink Salmon

After emergence from the gravel, pink salmon migrate quickly downstream to saltwater. They school up soon after emergence, travel as a school and, when attacked, do not hide in the substrate as do other salmonids. They spend less time in freshwater than other salmonids. A rapid exodus from freshwater to saltwater may be necessary for their survival. Coho, and, to a much less extent Dolly Varden, can be significant predators on pinks.

There may be behavioral differences between pinks found in small and large rivers. Schooling may be more common in large rivers and estuaries; however, in small rivers and streams, migration may occur as individuals. In small, coastal rivers, migration occurs at night, and nearly all fish may make it to saltwater in one night. Those that don't complete the migration in one night usually finish the trip the second night. In longer rivers where the spawning areas are greater distances upstream, migration may also occur during the daytime, particularly in the lower reaches of the river. Migrating pink salmon may be found anywhere in a river, from the surface to the bottom and from shore to shore, but they generally concentrate in the fastest flowing water.

Due to their limited freshwater residence and speedy migration, there may be very little impact of bank protection on pink salmon. Just as with chum salmon, secondary impacts of bank-stabilization activities, such as a change in species composition, may have a significant impact on juvenile pinks.

Sockeye Salmon

Most sockeye juveniles rear for a year in freshwater, usually in lakes. The vast majority of sockeye in Washington are lake-inlet spawners and simply move downstream to the lake immediately after emergence. Some sockeye are lake-outlet spawners and migrate upstream to the lake after emergence. After emergence, they may be swept downstream. When they are sufficiently big and strong, they seek out the shoreline and migrate along the bank back upstream to the lake in which they will continue to mature. There is limited rearing in streams; instead, they move quickly to a lake and reside there for a year or more. Lake-rearing juveniles are pelagic (living in open, deeper water), and bank-protection projects probably have little impact on them.

There are also stream-spawning sockeye in systems with no lakes. Their rearing habitats in these situations are not well known. Some biologists speculate that in large river systems, sockeye juveniles may act like coho, seeking deep river braids, off-channel sloughs, beaver ponds or other slack-water areas which act like small lakes. They have been found in winter in nonfreezing springs, spring ponds, creeks and side-channel sloughs. In some systems without lakes, juveniles may migrate directly to the estuary at age zero (younger than one year) and stay to grow in the tidewater sloughs.

Smolts usually migrate to the ocean in schools, often at night, swimming faster than the current. Smolts migrate near the surface in the main channel rather than in the quieter, near-shore area. They have been sampled migrating in the same midchannel locations as steelhead and yearling chinook. In the Columbia River, they can travel at rates of 40 kilometers per day.

Juvenile sockeye do not appear to be often associated with near-shore areas for any part of their freshwater life. Therefore, there is probably little overall impact of bank-protection projects on sockeye stocks. Barriers to access into river sloughs may have a large impact on sockeye that rear in rivers. Secondary impacts of bank-stabilization activities, such as a change in species composition, may have a significant impact on juvenile sockeye.

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